of experiment, I can entertain no doubt that they do so hold far enough to afford assurance that we can transport (with fuel for a considerable journey and at speeds high enough to make us independent of ordinary winds) weights many times greater than that of a man." And

"I desire to add as a final caution, that I have not asserted that planes such as are here employed in experiment, or even that planes of any kind are the best forms to use in mechanical flight, and that I have also not asserted, without qualification, that mechanical flight is practically possible, since this involves questions as to the method of constructing the mechanism, of securing its safe ascent and descent, and also of securing the indispensable condition for the economic use of the power I have shown to be at our disposal—the condition, I mean, of our ability to guide it in the desired horizontal direction during transport,—questions which, in my opinion, are only to be answered by further experiment, and which belong to the inchoate art or science of aerodromics, on which I do not enter."

The problems of Langley are still problems, and we have very much to learn about the control of aeroplanes. An interesting commentary on Langley's work is provided by the fact that on October 19 the world's record for gliding flight was obtained on a replica of the Langley machine and not by a glider following the modern conventional aeroplane. It would be wrong, I think, to argue superiority of type for the successful glider, but it is a not unwelcome reminder of the enormous progress made by a scientific pioneer at a time when science in aviation is at a very low ebb.

The Early History of the Land Flora.[1]

By Dr. D. H. SCOTT, F.R.S.

II.

WHEN we reach the Upper Devonian flora we find ourselves in the midst of a comparatively familiar vegetation. A few of the early forms may have survived, but the bulk of the plants were highly organised Vascular Cryptogams or Spermophytes. While in the Early Devonian no true Ferns have been found, a branched, naked rachis being the nearest approach to a frond, the later vegetation has been called the Archæopteris flora, after the magnificent ferns or fern-like plants of that genus, of which the famous *A. hibernica* is the type. We do not, however, know for certain whether these fine plants were really Ferns, or fern-like seed-plants. The presence of true Ferns is more surely attested by Dawson's Asteropteris, from the State of New York, which has the structure of a Zygopterid, a group well known from Carboniferous rocks. Lycopods had attained a very high development, as shown especially by the genus Bothrodendron, of which the large heterosporous cones are known.

The now extinct group of the Sphenophyllums, characteristic of Carboniferous times, had also made its appearance in the Upper Devonian flora; the whorled leaves of these early forms were deeply cut, not wedge-shaped as in most of the later representatives. Nathorst's genus Hyenia, which already appears in the Middle Devonian, may probably have been a precursor of the Sphenophylls.

Another family, represented by Pseudobornia, of Nathorst, from Bear Island, is only known from the Upper Devonian. It was a large plant, with whorled leaves, palmately divided, and further cut into narrow segments, while the long cones are believed to have produced spores of two kinds. Pseudobornia is at present quite isolated; its affinities may be either with the Sphenophylls or the Horsetails. Apart from this case, the Equisetales do not appear to be represented among our present Devonian records, for the evidence for the occurrence of Archæocalamites at that period seems to be inadequate. The group, however, was so well developed in Lower Carboniferous times that there can be no doubt it had appeared long before.

The best proof of the presence of seed-plants in the Upper Devonian is to be found in the occurrence of petrified stems, which, from their organisation, must presumably have belonged to advanced Gymnosperms. The genus Callixylon, apparently allied to the Lower Carboniferous Pitys, has a peculiar and beautiful structure in the secondary wood, the pits being localised in definite groups. The wood appears more highly differentiated than that of most living Conifers.

Thus the main lines of subsequent evolution were already well laid down in Upper Devonian times. We know practically nothing of their origin. Some botanists believe that the higher plants may have had a common source in some group, already vascular, such as the Psilophytales, while others hold that the main phyla have always been distinct, from the Algal stage onwards. The existence of these rival monophyletic and polyphyletic hypotheses, both maintained by able protagonists, shows how little definite knowledge of the evolutionary history we possess.

The Lower Carboniferous flora bears a close general resemblance to the Upper Devonian, but is much better known. The wealth of forms is, indeed, so great, that only the merest outline of the main features can be given here.

The Lycopods were abundantly developed. Many species of Lepidodendron and Lepidophloios are known, not only by external characters, but often by anatomical structure. While the primary ground plan of their anatomy was not unlike that of some of the simpler Lycopods of our own day, most of the old forms developed a considerable zone of secondary wood, and a massive periderm. They were, in fact, adapted to play the part of forest trees. The genus Sigillaria, however, so important in the Upper Carboniferous flora, was still scantily represented.

As regards their fructification, the Lower Carboniferous Lycopods had attained the highest level which the class ever reached. Not only were their cones constantly (so far as observed) heterosporous, with an extreme differentiation of the two kinds of spore, but some of them even developed a kind of seed, a structure quite unknown among Club-mosses of later than Carboniferous age. In the seed-like fructification

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[1] Continued from p. 607.

(Lepidocarpon) a single megaspore only came to maturity, constituting the embryo-sac, while an integument, like a seed-coat, grew up round the sporangium.

The prothallus is sometimes well preserved, both in the seed-like bodies and in the more ordinary megaspores. In the latter (*Lepidostrobus Veltheimianus*), Dr. Gordon has recorded a perfectly typical archegonium, showing that the details of reproduction in these old Lycopods were the same as in their modern heterosporous representatives.

The best-known member of the Horsetail race was Archæocalamites, remarkable for the long leaves, often repeatedly forked, very different from the foliage which we are accustomed to associate with the Equisetales. The later Calamites were more or less intermediate in this respect. Anatomically, the Calamites, whether of Lower or Upper Carboniferous age, developed much secondary wood, and, like many contemporary Lycopods, became trees. The Lower Carboniferous Protocalamites is remarkable for possessing primary wood, centripetally formed, thus presenting some analogy with the Sphenophylls, in which this tissue is highly developed.

The cones attributed to Archæocalamites are, curiously enough, intermediate in structure between modern Equisetum cones and those of the Upper Carboniferous Calamites, for sterile bracts were either absent, or developed only at long intervals. In Equisetum, of course, they are absent altogether, while in the well-known Calamostachys and allied Upper Carboniferous fructifications, the sterile whorls are equal in number to the alternating fertile verticils. It must be admitted, however, that our knowledge of Lower Carboniferous fructifications of this group is still somewhat scanty.

The Sphenophylls of the period were already very advanced, and in the genus Cheirostrobus appear to have reached their zenith. The great cones of this striking plant, with their elaborate and perfect apparatus of compound sporangium-bearing organs, and protective sterile appendages, are certainly the most complex cryptogamic fructifications known, from any period. Thus, in certain directions, the Lower Carboniferous plants had attained a height of development which has never since been equalled.

Sphenophyllum itself still had, for the most part, the deeply cut leaves of the Upper Devonian species. Where the anatomy is known (*S. insigne*, from Burntisland), it is of the same general type as in the later Upper Carboniferous forms, but apparently somewhat less specialised. It is worth remarking, that all the Sphenophyllums formed secondary wood, though they were small plants. Thus growth in thickness by cambium was not confined to arborescent forms in Palæozoic times, any more than it is now.

As regards the affinities of the Sphenophylls, some relation to the Horsetail stock seems evident, as indicated by the whorled leaves, the general organisation of the cones, and the detailed structure of the sporangia. Presumably these two lines sprang from a common source, but what it was is still unknown. Further affinities, once suggested, with the Lycopods and the recent Psilotaceæ have not been confirmed and are probably illusory. Neither has Lignier's hypothesis of a common origin of both branches of the Articulatæ from Ferns, gained any support from the fossil record. The Articulatæ, as a whole, remain a completely isolated phylum.

The Ferns of the Lower Carboniferous were well developed and varied. We meet with the usual difficulty in distinguishing between the fronds of true Ferns, and those of the so-called "Seed-Ferns," which simulated them in habit. Where, however, anatomical characters are available, we find no approximation whatever between the two groups. Pteridosperms and Ferns at all times show themselves perfectly distinct, whenever our knowledge admits of an adequate comparison.

We have fairly abundant structural material of Lower Carboniferous Ferns, but it seems that practically all of it represents the group called Primofilices by Arber, who by this name meant to suggest age, not primitiveness. They were curious plants, and many of them must have been very unlike any Ferns now living. Unfortunately, our knowledge of their habit is by no means equal to that of anatomical detail.

The chief family in the Lower Carboniferous is that of the Zygopterids, of which several genera are represented. As we have seen, this family had already appeared in Upper Devonian times. The vascular cylinder of the stem shows some differentiation of the wood into a central region (either a mixed pith or a core of small, short tracheids), and a wide outer zone of larger elements. The petiole always has a peculiar structure, with a bilateral strand (often of complex form) giving off branch-bundles to the right and left. It is remarkable that the genus Clepsydropsis, once thought primitive on account of its simple petiolar structure, has been shown to possess an exceptionally high organisation of the stem.

The most striking point is the morphology of the frond. Even where there were only two series of pinnæ (as in normal compound leaves) their plane was not parallel to that of the main rachis, but at right angles to it. Moreover, in several genera there was the greater peculiarity that the pinnæ were in four rows, two rows on each side, a condition unexampled in ordinary leaves. In Stauropteris this quadriseriate branching was repeated in successive ramifications, so that the form of the whole frond was compared by Lignier to a bush. In this genus it is practically certain that the leaflets had no blade, and throughout the family there is rarely any proof of its presence.

The other Lower Carboniferous family of Primofilices, the Botryopterideæ, is at present represented for that period by a single species, the *Botryopteris antiqua* of Kidston, a plant in all respects of simpler organisation than the Zygopterids, and apparently more like an ordinary Fern.

Sporangia are known in several cases. Those of Stauropteris were borne singly on ultimate branches of the frond; they had no annulus, and are very similar to the sporangia associated with the Early Devonian Asteroxylon. In the fructification attributed to Diplolabis the sporangia are grouped in a sort of synangium, while those associated with Botryopteris have a biseriate annulus.

Both families show some affinity with the older members of the Osmundaceæ, while a relation to the Adder's Tongues has also been traced. But in both directions the connexion seems to be somewhat remote.

We are dealing, in the Lower Carboniferous Primofilices, with early races, already specialised on their own lines, and probably only indirectly connected with the main current of Fern-evolution.

The " Seed-Ferns " or Pteridosperms appear to have attained a great development in Lower Carboniferous times. A considerable variety of seeds is met with, and in some cases there is strong evidence for attributing them to plants with a fern-like foliage. In one such example, described by Nathorst, the seed (Thysanotesta) is remarkable for having a distinct pappus; it was thus adapted to wind-dispersal, like the achenes of Composites.

No less than six families, referred to Pteridosperms, are known by their anatomy. In only one is there any evidence as to the seed, but all these groups show, in their structure, a nearer relation to known " Seed-Ferns " than to any other phylum. The case referred to is that of Heterangium, a genus with a solid wood and no pith. A beautifully organised seed (Sphærostoma, Benson), obviously related to that of the Upper Carboniferous Lyginopteris, is found in close association with *Heterangium Grievii* and probably belonged to it. The two genera, Heterangium and Lyginopteris, are closely related, as shown by Dr. Kubart's discovery of intermediate anatomical features, in species of Millstone Grit age.

The Lyginopterideæ extend to the Upper Carboniferous, but the other five anatomical groups are peculiar to the Lower.[1] They show a great variety in structure, but none of them bear any anatomical resemblance to contemporary Ferns. Our knowledge of so many, more or less isolated, types indicates that we have only found a few relics of what was really a most extensive class of plants.

The family most richly represented is that of which Calamopitys is the type. A number of species of Calamopitys are known; they are plants with a pith (sometimes " mixed "), large leaf-trace bundles, and much secondary wood. The petioles, often of large size and with many vascular strands, have long been known as Kalymma. Some of the species, with dense secondary wood of a Coniferous type, have been separated by Dr. Zalessky under the name Eristophyton. An interesting new genus, Bilignea, in which the pith is replaced by a central column of short tracheids, has been discovered by Dr. Kidston.

Apart from the " Seed-Ferns," we have the remarkable Lower Carboniferous family of the Pityeæ, already represented, as we have seen, in the Upper Devonian. Pitys was a genus of trees, with a relatively large pith traversed by slender strands of wood, while the secondary wood was of an Araucarian type. The foliage was quite unknown until recently, when Dr. Gordon discovered the leaves attached to the twigs in a species from the shores of the Firth of Forth. The leaves are totally different both from those of any Pteridosperm and from the well-known foliage of the Upper Carboniferous Cordaiteæ; they rather resemble the needles of a Fir, though more complex in structure. Dr. Gordon suspects an affinity with Araucarian Conifers.

Perhaps the chief conclusion that follows from this hasty sketch of the earlier floras is the great distinctness of the main phyla.

The Lycopods may perhaps become merged, as we trace them back, in the early Devonian Psilophytales, but nowhere approach any other group.

The Articulatæ appear as an isolated phylum throughout.

The Ferns may have come from thalloid plants, through some of the forms of Early Devonian age, where the frond is only represented by a bladeless rachis. The " Seed Ferns " now appear as a totally distinct line, parallel in certain respects to the true Ferns, but nowhere joining them, unless it be in some common thalloid source, about the Psilophytales level.

The higher Gymnosperms, represented in the period considered by Pitys and its allies, may have passed through an earlier Pteridosperm stage, but this is not proven. The Spermophyta generally may, for all we know, be as ancient as any other vascular plants.

Thus phylogeny still eludes us, though it remains the ultimate goal of the palæontologist.

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[1] Space does not admit of any account of their remarkable characters. The five type-genera are: Rhetinangium, Stenomyelon, Protopitys, Cladoxylon and Calamopitys.

Obituary.

DR. C. G. KNOTT, F.R.S.

THE sudden death of Dr. C. G. Knott, reader in applied mathematics in the University of Edinburgh, and general secretary of the Royal Society of Edinburgh, has deprived physical science of a devoted follower and an accomplished exponent. On Wednesday, October 25, he was lecturing as usual and attending, in the afternoon, to the business of the Royal Society. At night he was taken ill and died of heart failure in a few hours.

Born at Penicuik in 1856, Knott entered the University of Edinburgh in 1872 and soon joined a little band of enthusiastic workers in the laboratory of Prof. Tait. To study under that great teacher was a privilege and an inspiration. The laboratory, then a new feature in university physics, was a small attic, meagrely equipped. Only a few of the best pupils cared to seek admission; they plunged at once into research, either sharing in the investigations on which Tait happened to be engaged, or undertaking some independent inquiry of their own. Tait was then collecting data for his thermoelectric diagram, and Knott's training was to measure the electromotive forces between pairs of some twenty different metals, through a wide range of junction temperatures. He also began the series of magnetic researches he was afterwards to pursue with the help of his own Japanese pupils. In 1879 he was appointed Tait's assistant, but gave up that post in 1883 when he became professor of physics in the University of Tokyo. After eight years as professor in Japan he returned, in 1891, to his own University of Edinburgh, where he spent the rest of his life, at first as lecturer and later as reader in applied mathematics. He also acted as the official adviser of students reading for honours in mathematics